Thermophysical Properties of Semiconductor Process Gases Determined with Acoustic Techniques

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We measured the speed of sound in the process gases Cl_2, HBr, BCl_3, WF_6, C_2H_4O (ethylene oxide) and in the surrogate gases SF_6, CF_4, and C_2F_6. (The surrogate gases are used to in the calibrate mass flow controllers.) The data span the temperature range 200 K to 475 K and the pressure range 25 kPa to 1500 kPa or to 80% of the vapor pressure for condensable gases. The data were analyzed to obtain ideal-gas heat capacities C_p (T) with uncertainties of $0.001 \times C$p. The data were also used to parameterize model pair and three-body intermolecular potentials which, in turn, were used to estimate the properties of the gases up 1000 K, a temperature well above the range of the data. From the model potentials, we calculated the equation of state $P(V,T)$ and the viscosity $\eta(T)$. For gases where other data exist, we find the errors in calculated properties are less than $0.001 \times V$ and $0.1 \times \eta$. The thermal conductivity $\kappa(T)$ was estimated from $\eta(T)$ and Cp with an uncertainty of approximately $0.1 \times \kappa$. We plan similar measurements in other process gases and gas mixtures, direct acoustic measurements of the transport properties, and the dissemination of the results in a user-friendly data base.